

Studies on adaptability of *Populus bolleana* and other Poplar trees in northwest Shanxi Province

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Abstract: Through five years (1996-2000) experiment, the growth characteristics and resistance to insect and cold of the seven poplar varieties including *P. popularis*, *P. opera*, *P. pseudo-simonii*, *P. beijingensis*, *P. bolleana*, *P. x euramericana* and *P. simonii*, which were planted in loess hilly land in northwest Shanxi Province, were tested under different planting densities and site conditions. A randomized block design and three times repetition were adopted in the test. Based on the test results in arid and cold area of the northwest Shanxi, the hybrid poplar trees taking *Populus cathaysna* as their female parent could be selected for afforestation, such as *P. popularis* and *P. opera*, and the growing space of single plant should be larger than 20 m². *P. bolleana* as an introduced tree species grows well in this area, but its growth is likely affected by ground water condition. On the site with relatively abundant soil water, *P. bolleana* usually suffer from frost crack at its trunk base. As a result, *P. bolleana* is suited to planting in the site where is short of soil water. *P. x euramericana* is not suitable for large-scale afforestation, especially in arid slopes and ridges of loess hilly land.

Key words: Poplar trees; Arid and cold area; Adaptability; Shanxi Province

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Introduction

The northwest area of Shanxi Province was arid and cold, short of vegetation and suffered from serious wind and sandstorms (Shanxi Forestry Institute 1989). During the late 1960s, large area of poplar and robinia plantations was established in northwest area of the Province. However, for improper selection of species, great planting density and extensive management, most of the poplar plantations grew to "small-old-tree", accompanied by serious insect injury, and the value of wood utilization was very low (Guo 2000). The *Robinia pseudoacacia* likely suffered from frozen injury and hardly develops to forest. Only in some areas where is out of wind and facing sun, could it grow well. In order to enrich local tree species for afforestation, improve the protective effects of afforested land and utilization value of wood, we conducted the variety test of poplar trees and the introduction test of *P. bolleana* in recent years.

Study area

The study sites were located in Yinshan Forest Farm of Hequ County, Zhangjiaping Forest Farm of Wuzhai County and Yijing Forest Farm of Shenchi County in Shanxi Province. In line with the natural

regionalization of Shanxi, the study area was in semi-arid warm sylvosteppe and arid steppe gray-cinnamonic soil zone, with an annual average temperature of 5.0-9.0°C, the extreme minimum temperature -23°C and annual precipitation of 450-500 mm. The soil was gray-cinnamonic soil with a sandy loam texture and a bad structure. Site conditions of test field were shown in Table 1. The natural vegetation took grasses as the dominant factor. It was a kind of grassland consisting of needlegrass, digitate goldenbeard and wormwood. The earth's surface was intact with a slope of about 5°, and most part of it was farmland for growing spring wheat, naked oats, millet and potatoes.

Poplar multi-variety test

Test method

The test adopted a randomized block design, three times repetition, 2 m×3 m of row spacing and 72 stocks per plot. The test varieties were *P. popularis*, *P. opera*, *P. pseudo-simonii*, *P. beijingensis*, *P. bolleana*, *P. x euramericana* and *P. simonii*. Soil preparation was done one year before planting, and the specifications of the planting holes was 0.8 m×0.8 m×0.8 m. Normal planting method was used with once inter-tillage over every summer and uniform management measures.

For all the seven test varieties, the planting stock was 1~2-year-old. A five-years old *P. simonii* stand was used as control. The damaged degree by trunk-damage insect is defined as Light (less 5% of

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the whole stock is injured), middle (5%-10%) and serious (over 10%). The frozen injury was divided into five grades: I--the plants were in good condition after overwintering, II--tip frozen occurred and the frozen

part was below 1/3 of above-ground part of plants, III--the frozen part covered 1/3~1/2 of the trunk, IV--the frozen part was over 1/2 of the trunk, and V--whole plant was dead.

Table 1. Site conditions of various kinds of test fields

| Locations | Landform | Elevation (m) | Annual average temperature(°C) | Soil water Content (%) | Notes |
|------------------------|--------------|---------------|--------------------------------|------------------------|--|
| Yinshan, Hequ County | Gentle slope | 1300 | 6.8 | 7.9 | The soil water content was referred to the soil water content of 0-30 cm depth of soil layer in May in normal year |
| Zhangjiaping, Wuzhai | River bed | 1400 | 5.6 | 12.1 | |
| Yijing, Shenchu County | Gentle slope | 1400 | 6.2 | 9.8 | |

Test analysis

Table 2 showed the growing conditions of the tested poplar varieties in three site conditions (Hequ, Wuzhai and Shenchu counties). According to the contrast test in the three locations, under no irrigation condition in northwest area of the province, the hybrid varieties taking *P. pseudo-simonii* as its female parent could be selected for afforestation. There is no sig-

nificant difference in temperature, precipitation and soil conditions for three locations. The plant growth was obviously affected by ground water. In the site with relatively abundant soil water, *P. beijingensis* and *P. popularis* grew well, but *P. bolleana* likely has frost crack at its trunk base. *P. × euramericana* was not suitable for large-scale afforestation, especially in arid slopes and ridges

Table 2. Increments of different varieties of poplar under various site conditions

| Varieties | Hequ County | | | | Wuzhai County | | | | Shenchu County | | | |
|------------------------------|-------------|---------|---------------|---------------|---------------|----------|---------------|---------------|----------------|----------|---------------|---------------|
| | Tree height | d. b.h. | Insect injury | Frozen injury | Tree height | d. b. h. | Insect injury | Frozen injury | Tree height | d. b. h. | Insect injury | Frozen injury |
| | /m | /cm | degree | degree | /m | /cm | degree | degree | /m | /cm | degree | degree |
| <i>P. popularis</i> | 5.5 | 5.3 | L | I | 9.8 | 10.3 | L | I | 6.0 | 5.7 | L | I |
| <i>P. opera</i> | 5.6 | 5.1 | L | I | 9.6 | 9.9 | L | I | 6.1 | 5.7 | L | I |
| <i>P. pseudo-sim. × eura</i> | 7.0 | 6.6 | L | I | 10.2 | 10.8 | L | I | 6.3 | 6.2 | L | I |
| <i>P. beijingensis</i> | 4.4 | 3.8 | M | I | 9.3 | 11.4 | L | I | 5.6 | 4.7 | L | II |
| <i>P. bolleana</i> | 5.9 | 4.9 | L | I | 9.3 | 8.7 | L | II | 5.9 | 4.4 | L | I |
| <i>P. × eura</i> | 3.5 | 3.3 | M | III | 7.8 | 5.8 | L | II | 4.0 | 3.6 | L | III |
| <i>P. simonii</i> | 3.0 | 2.8 | M | I | 9.3 | 8.8 | L | I | 3.2 | 2.4 | M | I |

L—Light; M—middle;

Effects of the planting density on varieties

The test field was in gentle slope hilly-land, located in Yinshan Forest Farm of Hequ County. The test varieties were *P. simonii*, *P. simo-nigra*, *P. bolleana*. 16 stocks per plot, randomized block design with tree times repetition were adopted. The planting stock age was 1-2.

The increment of the trees in different planting densities was shown in Table 3. In northwest area of Shanxi, the water condition was a limiting factor for plant growth. Over the test fields, In the case of big planting density, the competition for water between plants was intense and the soil water was short of supply, as a result, the plants grow slowly. With decreasing of planting density, the growth rate of trees was increased, as the growing space for one plant getting large. According to large-area investigations under this site conditions, when one want to get wood

with a breast-height diameter > 15 cm, the growing spacing for one plant should be larger than 20 m².

Table 3. Effects of planting density on growth of trees

| Varieties | Planting Density (m × m) | Stand age /a | Tree height /m | Diameter at breast-height /cm |
|----------------------|--------------------------|--------------|----------------|-------------------------------|
| <i>P. simonii</i> | 2 × 2 | 10 | 4.4 | 4.3 |
| <i>p. simo-nigra</i> | 2 × 2 | 10 | 5.1 | 4.6 |
| <i>P. opera</i> | 2 × 2 | 10 | 6.4 | 5.8 |
| <i>P. bolleana</i> | 2 × 2 | 10 | 6.0 | 5.3 |
| <i>P. simo-nigra</i> | 3 × 4 | 7 | 5.3 | 5.7 |
| <i>P. opera</i> | 3 × 4 | 7 | 6.8 | 7.5 |
| <i>P. bolleana</i> | 3 × 4 | 7 | 5.3 | 4.1 |
| <i>P. simo-nigra</i> | 4 × 4 | 8 | 8.6 | 10.0 |
| <i>P. opera</i> | 4 × 4 | 8 | 8.7 | 10.0 |
| <i>P. bolleana</i> | 4 × 4 | 8 | 7.6 | 7.5 |

Adaptability of *P. bolleana*

20 trees of *P. bolleana* plantations were investigated in the same or nearly the same planting density at different elevations. The even stand age is 7. *P. opera* was used as control (see Table 4).

From Table 4, regardless of *P. bolleana* or *P. opera*, it is obvious that the increment of trees varied with variation of elevation. At 850 m, the water collecting area of Alee-trees is large and the

evapo-transpiration capacity is small, as a result, the increment of individual tree was therefore great. In normal case, the soil water condition over plane ridges was the worst and the increment of individual tree was the smallest. The growth of *P. bolleana* was not so good as *P. opera* in good soil conditions, while at high elevation and under bad conditions the *P. bolleana* grew better than *P. opera*. That is to say, the drought-resistant capacity of *P. bolleana* was greater than *P. opera*.

Table 4. Increment comparison of *P. bolleana* and *P. opera* under different site conditions

| Elevation (m) | Site conditions | Tree species | Density /m × m | Tree height /m | Diameter at breast-height /cm | |
|------------------|-----------------|--------------------|-------------------|-------------------|-------------------------------|---------|
| | | | | | Mean | maximum |
| 850 | Wayside | <i>P. bolleana</i> | 7 × 2 | 12.6 | 9.6 | 12.1 |
| | | <i>p. opera</i> | | 12.9 | 13.1 | 15.4 |
| 1100 | Gentle slope | <i>P. bolleana</i> | 4 × 3 | 8.5 | 7.6 | 9.8 |
| | | <i>p. opera</i> | | 8.3 | 9.4 | 13.1 |
| 1300 | Plane ridge | <i>P. bolleana</i> | 4 × 3 | 6.7 | 5.4 | 8.1 |
| | | <i>p. opera</i> | | 5.8 | 5.6 | 8.3 |

For evaluating the growing process of *P. bolleana*, the analytical trees were selected from the wayside trees in Yinshan Forest Farm of Hequ County, at 850 m of elevation, with 2 × 7 m of row spacing.

The analytical information about the diameter at breast-height and the tree height was shown in Table 5 and Table 6. As for increment of diameter at breast height, *P. opera* grew more quickly at age of 3-8 years, while *P. bolleana* grew more quickly at age of 4-10. The annual increment of *P. bolleana* in diameter

was lower than that of *P. opera*, but at age of 15, the *P. bolleana* still has a big increment. This indicates that *P. bolleana* has a relative great increment at the later stage.

There was no great difference in tree height growth between *P. opera* and *P. bolleana*, and both of them grew quickly in first 7 years. The growing process of *P. bolleana* tallies with that in its original growing place (South Xinjiang) (Li 1993), so the *P. bolleana* can be developed in this area.

Table 5. Analytical information about the breast-height diameter of *P. bolleana* and *P. opera*

| Tree species | Tree's number | Increment in diameter at breast height /cm | | | | | | | | | | | | | | | |
|--------------------|--------------------|--|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| | | Tree age /a | | | | | | | | | | | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | (15) |
| <i>P. bolleana</i> | 2 | 0.5 | 1.2 | 1.7 | 2.5 | 4.1 | 5.5 | 7.1 | 8.2 | 9.3 | 10.5 | 11.4 | 12.2 | 13.0 | 14.1 | 14.8 | 15.6 |
| | 6 | 0.7 | 1.7 | 2.4 | 3.5 | 4.1 | 5.1 | 6.4 | 7.7 | 8.8 | 9.8 | 10.8 | 11.8 | 12.8 | 13.6 | 14.9 | 15.7 |
| | 12 | 0.5 | 1.0 | 2.0 | 3.2 | 5.6 | 7.0 | 8.2 | 9.4 | 10.1 | 11.2 | 11.9 | 12.6 | 13.4 | 13.9 | 14.6 | 15.2 |
| | Average | 0.6 | 1.3 | 2.0 | 3.1 | 4.6 | 5.9 | 7.2 | 8.4 | 9.4 | 10.5 | 11.4 | 12.2 | 13.4 | 13.9 | 14.8 | 15.5 |
| | Annual average | 0.6 | 0.75 | 0.67 | 0.77 | 0.92 | 0.98 | 1.03 | 1.05 | 1.04 | 1.05 | 1.03 | 1.02 | 1.01 | 0.99 | 0.98 | 1.03 |
| | Successive average | 0.6 | 0.7 | 0.7 | 1.1 | 1.5 | 1.3 | 1.3 | 1.2 | 1.0 | 1.1 | 0.9 | 0.8 | 0.9 | 0.8 | 0.9 | |
| <i>P. opera</i> | 4 | 0.8 | 1.9 | 3.8 | 5.4 | 9.4 | 11.4 | 12.9 | 13.8 | 14.6 | 15.5 | 16.6 | 17.6 | 18.3 | 18.8 | 19.2 | 20.2 |
| | 9 | 0.6 | 1.1 | 2.0 | 5.4 | 9.0 | 12.0 | 13.8 | 15.1 | 16.2 | 17.5 | 18.7 | 19.4 | 20.2 | 20.6 | 20.8 | 21.6 |
| | 3 | 0.6 | 1.9 | 4.2 | 6.6 | 7.5 | 10.0 | 11.0 | 12.1 | 12.8 | 13.5 | 14.4 | 15.1 | 16.0 | 16.8 | 17.4 | 18.7 |
| | Average | 0.7 | 1.6 | 3.3 | 5.8 | 8.6 | 11.1 | 12.6 | 13.7 | 14.5 | 15.5 | 16.6 | 17.4 | 18.2 | 18.7 | 19.1 | 20.1 |
| | Annual average | 0.7 | 0.82 | 1.11 | 1.45 | 1.73 | 1.86 | 1.80 | 1.71 | 1.61 | 1.55 | 1.51 | 1.45 | 1.40 | 1.34 | 1.28 | |
| | Successive average | 0.7 | 0.9 | 0.7 | 2.5 | 2.8 | 2.5 | 1.5 | 1.1 | 0.80 | 1.0 | 1.1 | 0.8 | 0.8 | 0.5 | 0.4 | |

Table 6. Analytical information about the tree height of *P. bolleana* and *P. opera*

| Tree species | Tree's number | Increment in tree height/ m | | | | | | | | | | | | | | | |
|--------------------|--------------------|-----------------------------|-----|------|-----|------|------|------|------|------|------|------|------|------|------|------|------|
| | | Tree age /a | | | | | | | | | | | | | | | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | (15) |
| <i>P. bolleana</i> | 2 | 1.8 | 3.6 | 5.6 | 7.6 | 9.6 | 11.6 | 13.6 | 15.5 | 16.9 | 16.9 | 17.2 | 17.4 | 17.7 | 18.0 | 18.3 | 18.3 |
| | 6 | 1.8 | 3.6 | 5.6 | 7.6 | 9.6 | 10.6 | 11.6 | 12.6 | 13.6 | 14.6 | 14.9 | 15.2 | 15.5 | 15.8 | 16.2 | 16.2 |
| | 12 | 1.8 | 3.6 | 5.6 | 7.6 | 9.6 | 11.6 | 13.6 | 14.6 | 14.8 | 15.1 | 15.4 | 15.7 | 16.0 | 16.3 | 16.6 | 16.6 |
| | Average | 1.8 | 3.6 | 5.6 | 7.6 | 9.6 | 11.3 | 12.9 | 14.3 | 15.0 | 15.5 | 15.8 | 16.1 | 16.4 | 16.7 | 17.0 | |
| | Annual average | 1.8 | 1.8 | 1.87 | 1.9 | 1.92 | 1.88 | 1.85 | 1.78 | 1.67 | 1.55 | 1.44 | 1.34 | 1.26 | 1.19 | 1.14 | |
| | Successive average | 1.8 | 1.8 | 2.0 | 2.0 | 2.0 | 1.7 | 1.6 | 1.4 | 0.7 | 0.5 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | |
| <i>P. opera</i> | 4 | 1.8 | 3.6 | 5.6 | 7.6 | 8.6 | 9.6 | 11.6 | 13.6 | 15.6 | 16.0 | 16.6 | 16.8 | 17.2 | 17.4 | 17.7 | |
| | 9 | 1.8 | 3.6 | 5.6 | 7.6 | 9.6 | 11.6 | 13.6 | 14.2 | 14.9 | 15.6 | 16.0 | 16.3 | 16.6 | 16.9 | 17.2 | |
| | 3 | 1.8 | 3.6 | 5.6 | 7.6 | 9.6 | 11.6 | 12.2 | 12.9 | 13.6 | 14.6 | 15.6 | 16.6 | 16.8 | 17.0 | 17.1 | |
| | Average | 1.8 | 3.6 | 5.6 | 7.6 | 9.3 | 10.9 | 12.5 | 14.7 | 14.7 | 15.4 | 16.1 | 16.6 | 16.9 | 17.1 | 17.3 | |
| | Annual average | 1.8 | 1.8 | 1.87 | 1.9 | 1.85 | 1.82 | 1.78 | 1.63 | 1.63 | 1.54 | 1.46 | 1.38 | 1.30 | 0.22 | 1.16 | |
| | Successive average | 1.8 | 1.8 | 2.0 | 2.0 | 1.7 | 1.6 | 1.6 | 1.1 | 1.1 | 0.7 | 0.7 | 0.5 | 0.3 | 0.2 | 0.2 | |

Conclusion

Under the conditions without irrigation in Northwest Shanxi, the hybrid poplar varieties taking *P. simonii* and *P. pseudo-simonii* as it's female parent could be selected for poplar afforestation, such as *P. popularis*, *P. opera*, *P. simo-nigra*, *P. pseudo-simonii* × *P. euramericana*, etc.. *P. × euramericana* was not suitable for large-scale afforestation. Under good water conditions, *P. bejinensis* could be used.

Water condition was a limited factor affecting growth of poplar trees in the area. Under arid conditions, enough growing space was needed for normal growing of poplar trees. According to investigation results, the growing space of individual tree should be larger than 20 m².

In northwest area of Shanxi Province, under much

poor soil water condition, *P. bolleana* grows better than *P. opera*. According to the analytical information for 15 years, *P. bolleana* was suitable for this area. It was also a good material for variety improvement. Under good water conditions, *P. bolleana* likely suffers from frost crack at trunk base.

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